SHORT COMMUNICATION

Standardization of Digital Human Models

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Abstract. Digital human models (DHM) have evolved as useful tools for ergonomic workplace design and product development, and found in various industries and education. DHM systems which dominate the market were developed for specific purposes and differ significantly, which is not only reflected in non-compatible results of DHM simulations, but also provoking misunderstanding of how DHM simulations relate to real world problems. While DHM developers are restricted by uncertainty about the user need and lack of model data related standards, users are confined to one specific product and cannot exchange results, or upgrade to another DHM system, as their previous results would be rendered worthless. Furthermore, origin and validity of anthropometric and biomechanical data is not transparent to the user. The lack of standardization in DHM systems has become a major roadblock in further system development, affecting all stakeholders in the DHM industry. Evidently a framework for standardizing digital human models is necessary to overcome current obstructions.

Keywords: Digital Human Model, standardization, computer manikin, body template, virtual human

Practitioner Summary. This short communication addresses a standardization issue for digital human models, which has been addressed at the International Ergonomics Association Technical Committee for Human Simulation and Virtual Environments. It is the outcome of a workshop at the DHM 2011 symposium in Lyon, which concluded steps towards DHM standardization that need to be taken.

1. Introduction

Digital human models are of great importance in research and industry: They enable scientists to carry out computer-aided studies on human postures and motions with the option to easily vary anthropometric as well as biomechanical parameters of virtual surrogates (Chaffin 2005). While multi-body, biomechanical (e.g. Christensen et al. 2003), finite element (FEM) (e.g. Siefert et al. 2008), and human segmental models (e.g. Zhuang et al. 2010) are considered DHM in this framework, psychophysical or cognitive models (Bellet et al. 2011), lumped-parameter and biodynamic models (Griffin 2001) will be considered out of scope.

The simulation approach increases the amount of possible analyses, while at the same time decreasing effort, time and cost due to omission of physical experiments with real subjects. In practice digital human models help to improve design and usability of products and work systems in early stages of product and process design. Again, effort, time and cost are optimized due to the more efficient organization of iterative product and production process design phases.

It is for this reason that a number of different, commercially available models with heterogeneous properties, capabilities, underlying algorithms, anthropometric and biomechanical data sets and even more scientific models for varying purposes have been developed in the past. A review of 63 posters and full papers presented at the First International Symposium on Digital Human Modeling of the International Ergonomics Association, held in Lyon July 2011, reveals more than 30 different full or partial models of the human body (e. g. hand-arm system, foot-leg system).

The large variability of existing digital human models, affecting for example naming of segments or joints, definition of global and local coordinate systems and degrees of freedom (DOF) of joint and segment motion as well as the embeded anthropometric and biomechnical data, makes it difficult to disseminate and compare results or exchange research ideas. Such may be due to the implementation of different algorithms, body and kinematic models, anthropometric assumptions or location of reference points. Furthermore, this makes it difficult to transfer validated research concepts into commercially distributed DHM software systems, which would broaden their basis for different usage.

This lack of standardization in DHM systems has become a major roadblock in further system development, equally affecting all stakeholders in the DHM industry. It is evident that a framework for standardizing digital human models is necessary to overcome current obstructions. Therefore the IEA Technical Committee on Human Simulation and Virtual Environments has formed a sub-committee for DHM standardization (WG S) in July 2011.

This paper summarizes the outcome of the first meeting of the WG S, including previous work, existing standards and guidelines, further requirements towards DHM standardization which were identified and the structure of required future activities.

2. Previous work

The sub-committee refers to previous, unpublished work done under the Society of Automotive Engineers (SAE) G-13 committee (Human Modeling and Technology). The SAE G-13 committee defined human modeling technology purpose as to improve design quality in relation to Human Factors, support definition of design requirements, demonstrate physical interaction between human and system, and identify risks and cost associated with man-in-the-loop (SAE International 2012). Although it was recommended to expand on this work, the SAE G-13 committee had difficulty defining standards for digital human models, as they concluded that doing so would impact a supplier's proprietary approach to building a manikin. Hence the G-13 workgroup went no further than a project comparing the anthropometric accuracy of various man models.

However, there is an apparent broad need in the wider digital human modeling community to better understand the model assumptions of specific DHM manikins, exchange or transfer information between DHM systems or DHM users, interpret DHM study results, justify DHM system selection or investment and support DHM development.

3. Standards and guidelines

The International Organization for Standardization (ISO) provides a basic standard for computer manikins including joint degrees of freedom in ISO 15536, as well as the detailed standards ISO 7250, ISO 15535 and ISO 20685 relating to human body measurements and their storage in databases. ISO/IEC 19774 "specifies a systematic method for representing humanoids in a network-enabled 3D graphics and multimedia environment". Besides, ISO TC108/SC4/WG14 (posture related to whole-body vibration) is drafting standard ISO TR 10687 on "Mechanical vibration – Description and determination of seated postures with reference to whole-body vibration" in the related domain of biodynamic modelling, with reference to coherent measurement and modelling.

Apart from international standards, the International Society of Biomechanics developed standards for the human body coordinate system (Wu and Cavanagh 1995) as well as for joint coordinate systems (Wu et al. 2002, Wu et al. 2005).

Furthermore, file formats are important for the exchange of data. Different quasi standards exist like for instance ASF/AMC (Acclaim 1994), BVH (Meredith and Maddock 2001), GMS (Luciani et al. 2006), C3D (Motion Lab Systems 2008), COLLADA (Collada Working Group 2006) or X3D (ISO 19775, ISO 19776, ISO 19777), which are in parts driven by the gaming and movie industry in conjunction with motion capturing.

Currently the German Engineering Association (VDI) is working on a comprehensive standard on human representation in the digital factory to provide an overview on current DHM practical and theoretical issues to be published as part 4 of the VDI Guideline 4499 (Zuelch 2012).

4. DHM standard considerations

From the above presented review of existing standards and guidelines, it becomes obvious that many approaches already exist to build upon for a DHM standard. Despite this advantage, proper integration of those existing standards and guidelines into a new DHM standard requires thorough consideration. The WG S raised additional questions, which were transferred into the following course of action:

4.1. ***Review of past and current efforts***

Before starting a new DHM standardization process, it is important to evaluate past as well as current efforts. Looking at past initiatives and their results builds the basis and enables a lessons learnt process.

Considering current efforts helps to avoid duplication of work. Examples for past and current efforts collected and structured so far, are briefly summarized in section 2 and 3.

4.2. ***Establish current needs of users and vendors***

Once the review has been completed, current needs of users as well as software vendors have to be analyzed and established. In view of associated developmental work and future implementation of the standard, a categorization into fundamental, important and useful issues should be pursued.

User needs should be divided into academic and practical needs. Scientists may require different standardization features than product and process engineers when using DHM systems.

Identifying software vendor needs is another challenging task, since the question may arise if standardization supports a software vendor's business model.

4.3. ***Scope of standardization***

The most critical question to answer remains the standardization targets. Fundamentally important is a standard human anatomic structure, with defined global and local coordinate systems, consistent naming and numbering of limb segments or joints, with their corresponding uniform degrees of freedom.

Further on, consideration is required for a DHM standard procedure and parametric model of linking anthropometric databases (ISO 15535) to a defined DHM human structure, in order to create proportions representative for a selected population. Moreover, it has to be assured that available anthropometric data (ISO 7250) can be used to calibrate the digital human model to be used as either an individual or boundary manikin.

Additionally, a standard data format would significantly facilitate the exchange of research results. A DHM standard data model should encompass an input section, containing information of model structure description, parameterization of the structure components (e. g. limb size, range of motion), anthropometric assumptions, hard points and kinematic drivers; as well as an output section, documenting the nature and results of simulations performed by a DHM.

Beyond these intrinsic parameters of a DHM standard, further extrinsic parameters encompassing all interaction between the user and one or several DHM have to be considered.

Thus a DHM standard should present an exemplary procedure on how to integrate the virtual ergonomic process into today's product and production design processes, in order to assure ergonomically valid results. A future standard has to define classes of accuracy for digital human models: How closely does a manikin need to match the human to produce adequate analysis for the application pursued? Finally, a standard test/ protocol should be worked out to allow comparisons between DHM performance and their compliance with the standard.

Out of scope for the working group but crucial to the success of DHM systems in terms of validity are the collection, processing and accurate usage of anthropometric, physiologic and biomechanical data (Van Sint Jan 20005). Current DHM systems contain different data sets and algorithms which are of limited transparency to the user. ISO standards (7250, 15535, 20685) and their further enhancements target to ensure consistent data collection in terms of methodology, sample size as well as data management and analysis. Their consideration needs to be mandatory for a DHM standard.

5. Future work

The presented aspects have been clustered and assigned to small working groups, which will develop drafts to be discussed at the regular plenary meetings. WG S plenary meetings are held in conjunction with TC HS & VE annual meetings.

The WG S is structured as a self-organized network within the TC HS & VE. The TC uses a LinkedIn social network platform as the main communication channel for exchanging ideas. WG S working sites have been established under the Standards Australia hub and an information share system managed by the German Federal Institute for Occupational Safety and Health (BAuA) provided by the German Federal Office of Administration. The IEA TC HS & VE and its WG S sub-committee are open for new members to join and invite participation beyond IEA membership.

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